Modelling user acceptance of wireless medical technologies

Katrin Arning, Sylvia Kowalewski, and Martina Ziefle

Human Computer Interaction Center (HCIC), RWTH Aachen University
Theaterplatz 14, 52062 Aachen, Germany
{arning; kowalewski; ziefle}@humtec.rwth-aachen.de

Abstract. Wireless medical technologies (WMT) offer an enormous potential to improve healthcare, e.g. by a continuous monitoring of patients' vital health parameters. As user acceptance is a key factor for WMT success, a model of acceptance for WMT-users and non-users was developed and empirically tested by applying structural equation modelling techniques (PLS). Based on a sample of N=305 participants the impact of different system architecture elements (device vs. wireless infrastructure) as well as user factors (knowledge, risk perception, and perceived control) on WMT acceptance was analysed. Perceived benefits and barriers as determining elements of WMT acceptance were quantified and guidelines for WMT system development, training and marketing were derived.

Keywords: technology acceptance, wireless, medical technologies, benefits, barriers, user factors, structure equation modelling, PLS

1 Introduction

Wireless medical technology (WMT) offers an enormous potential to improve healthcare and to reduce financial pressure on healthcare systems. Medical sensor networks are a typical example of a medical application of mobile communication network technologies. They allow for a continuous monitoring and wireless data transfer of vital health parameters over a long period of time. However, in order to fully exploit the potential of WMT, user acceptance should be considered as a key factor, as it is vital for both, patient's well-being and market success of a technology.

1.1 Acceptance of medical technologies

In information system research, the technology acceptance model (TAM [1]) and its successors (e.g. UTAUT [2]) are widely used to explain the acceptance of technical systems. The TAM assumes that the decision to use a technical system is determined by the behavioural intention to use the system, which is in turn influenced by the perceived ease of use and its perceived usefulness. Since the TAM was developed for a specific *technology type* with a less complex s*ystem architecture* (mainly stationary desktop computing) in a specific *application context* (job-related computer usage), covering specific *user groups* (computer-experienced workforce), it is increasingly doubted to be sufficient for a valid prediction of WMT acceptance (e.g. [3]).

Considerable research effort has been made to extend the scope of the TAM. In order to account for novel technology types such as wireless technologies, the Mobile Wireless Technology Acceptance Model (MWTAM) was proposed [4]. However, the MWTAM constructs still focus on a job-related ICT context, whereas the application context of medical technologies activates different acceptance patterns of usage drivers and barriers [5], related to trust, privacy and security issues [6]. Moreover, the characteristics of more heterogeneous user groups of WMT have to be considered. ICT-research identified demographic variables, experience, cognitive abilities, cultural factors, and personality factors as influential factors [7, 8]. Referring to WMT users, who might suffer from multiple physical and psychological restraints, an even stronger impact of individual factors on acceptance is expected. Regarding system architecture complexity, integrated wireless system architectures of WMT comprise a broader scope of technical elements (e.g. cellular networks, WLAN, RFID, GPS, devices). In contrast to well-accepted mobile devices, infrastructure elements of wireless technologies (e.g. base stations) often raise concerns or even fear about negative health effects [9]. This implies, that not only medical devices and interfaces, but also the underlying technical infrastructure should be considered in WMT acceptance research. As a final methodological aspect, the TAM constructs are too generic to provide concrete guidelines for WMT system design. Although the significance of constructs such as "usefulness" in explaining system acceptance was repeatedly proven, specific system characteristics, which actually make a system useful, were often not identified.

The present study therefore pursues a broader approach of investigating WMT acceptance, explicitly focusing on differential effects of WMT system architecture (devices and infrastructure), analysing underlying usage benefits and barriers in the medical application context as well as the impact of individual user factors on WMT acceptance. More specifically, the following research aims were aspired:

1. Quantification of WMT acceptance and investigation of system-architecture-related differences in WMT acceptance
2. Explanation of WMT acceptance by underlying usage benefits and barriers
3. Contrast of WMT acceptance for medical technology users and non-users
4. Analysis of user factors and their impact on WMT acceptance
5. Derivation of guidelines for WMT system development, trainings and marketing campaigns

2 Method

2.1 Questionnaire

The first part of the questionnaire assessed demographic data (age, sex, education, medical technology usage), the following parts assessed the items for our research model. Items for usage benefits and barriers of WMT were developed based on the findings of a focus-group study [5]. In order to familiarize participants with WMT, a detailed introduction into a WMT scenario of a blood pressure monitoring system, which automatically monitors and transfers data to medical care centres via mobile communication networks, was given. Multiple-choice items had to be answered on a six-point Likert scale ranging from 1 (do not agree at all) to 6 (fully agree).

2.2 Sample

The sample consisted of users and non-users of medical technologies (MedTec). According to diffusion of innovation theories [10], the non-user group can be regarded as "pre-adopter" or future user group of WMT in contrast to MedTec users. A total of 8.5% (N=24) participants reported to own and use a medical device (MedTec-users: M = 38.6 years, SD = 13.9, range 20-71 years, 58.3% female; MedTec non-users years: M = 33.9, SD = 11.8, range 17-72, 50.2% female). Since PLS allows to model rather small sample sizes, we contrasted MedTec users and non-users in order to investigate differences in acceptance patterns in both groups.

2.3 Statistical Analysis

ANOVAS and Partial Least Squares (PLS), a component-based structural equation modelling (SEM) technique, was employed. In contrast to covariance-based SEM techniques, PLS has less strict requirements on sample size and residual distribution [11], but allows for statistical modelling with formative and reflective constructs [12].

2.4 Research model and hypotheses

The following hypotheses were investigated in our research model:

H1 (User factors)

H1a: Knowledge is positively related to usage benefits, and negatively correlated to device threat and infrastructure threat.

H1b: Perceived control is positively related to usage benefits, and negatively related to usage barriers, device threat, and infrastructure threat.

H1c: Risk perception is positively related to device threat and infrastructure threat.

H2 (System Evaluation)

H2a Usage benefits are positively related to device acceptance and infrastructure acceptance.

H2b Usage barriers are positively related to device threat and infrastructure threat.

H2c Device threat is negatively related to device acceptance.

H2d Infrastructure threat is negatively related to infrastructure acceptance.

H3 (Acceptance)

H3a Device acceptance is positively related to infrastructure acceptance.

3. Results

3.1 PLS model quality

The analysis of the PLS measurement models demonstrated that all constructs and items had acceptable measurement properties. For the two formative constructs “usage barriers” and “usage benefits” the variance inflation factor varied from 1.01 to 2.3; therefore validity problems due to multicollinearity could be ruled out [11]. All reflective constructs met reliability criteria (Cronbach’s alpha > 0.7, Table 1) and discriminant validity criteria (Fornell-Larcker-Criterion, [10]).

3.2 Construct measurement results for MedTec-users and non-users

Descriptive statistics for measured constructs are presented in Table 1 and 2, along with the results of ANOVA analyses to assess differences between MedTec-users and non-users. Due to the small sample size of the *MedTec-user* sample there were no statistical differences on a 5% significance level, but the following descriptive results provide interesting result tendencies in user ratings.

User factors. *MedTec users* and *non-users* did not differ with regard to the user factors knowledge, risk perception and perceived control (Table 2).

Table 1: Reflective constructs characteristics and ANOVA results for group differences.

Construct	Group	M	SD	Cronbachs’s alpha	p
Knowledge about wireless technologies (1 Item)	MedTec-user Non-user	4.04 4.11	2.85 2.11	-	n.s.
Perceived Control (3 Items)	MedTec-user Non-user	3.62 3.54	1.36 1.03	.95 .80	n.s.
Risk Perception (2 Items)	MedTec-user Non-user	2.80 2.47	1.38 1.21	.86 .87	n.s.
Threat - Device (2 Items)	MedTec-user Non-user	2.33 2.69	0.67 0.94	.75 .87	n.s.
Threat - Infrastructure (2 Items)	MedTec-user Non-user	3.36 3.02	1.22 1.09	.88 .91	n.s.
Acceptance - Device (2 Items)	MedTec-user Non-user	4.30 4.09	1.40 1.42	.95 .95	n.s.
Acceptance- Infrastructure (2 Items)	MedTec-user Non-user	4.41 4.45	1.20 1.04	.99 .91	n.s.

System evaluation. The most important *usage benefit* for both user groups is the aspect of faster medical help in emergencies (Table 2). While *MedTec-users* judge improved safety as second important criterion, n*on-users* perceive higher mobility and flexibility as second most important benefit of using WMT. This benefit is, in contrast, the least important one for *MedTec-users*. Overall, results show that

MedTec-users favour benefits that concern safety and security aspects regarding their own health status.

Table 2: Formative construct characteristics and ANOVA results by groups.

	MedTec-user (N = 24)		Non-user (N=281)		
Usage Benefits	M	SD	M	SD	p
increased awareness of own health status	4.00	1.53	3.69	1.35	n.s.
improved safety due to medical monitoring	4.21	1.47	4.06	1.25	n.s.
faster medical help in emergencies	4.43	1.47	4.48	1.20	n.s.
higher mobility and flexibility	3.78	1.73	4.18	1.19	n.s.
Usage Barriers	M	SD	M	SD	p
surveillance due to medical monitoring	2.87	0.97	3.10	1.23	n.s.
loss of privacy	2.63	1.28	3.10	1.37	n.s.
data abuse	2.88	1.39	3.31	1.41	n.s.
dependency on technology	3.58	1.44	3.52	1.48	n.s.

Regarding WMT *usage barriers* two aspects turn out to be very interesting. Based on a six-point Likert-scale mean values above three can be seen as general compliance. Hence, Table 2 clearly shows that *non-users* in general agree with all barriers, i.e. perceive more usage barriers than *MedTec-users*. Second, the sole significant barrier for *MedTec-users* is “dependency of technology”. Nevertheless, high standard deviations on barriers of privacy and data security in the *MedTec-user-group* indicate a great amount of heterogeneity concerning these two barriers.

Referring to the evaluation of infrastructure and device we found an interesting result pattern. *MedTec-users* perceive a lower device threat than *non-users,* whereas perceived infrastructure threat is higher in *MedTec users* than in *non-users*. ANOVAs with the factors “technology level” (device vs. infrastructure) and “MedTec-usage” (user vs. non-user) confirmed this statistical interaction ($F(1,251) = 8.41$, $p < 0.01$).

Acceptance. Regarding acceptance ratings, we found that WMT was perceived positively on the device and on the infrastructure level. *MedTec-users* tend to show a greater acceptance of WMT on the device level than *non-users* do, whereas there is no difference in WMT infrastructure acceptance. Both user groups perceived a higher usefulness of WMT infrastructure than of WMT devices. For acceptance ratings no interaction was found in ANOVAs.

3.3 Structural model results for MedTec-users and non-users

The PLS analysis yielded path coefficients for the structural models of MedTec users (Fig. 1) and non-users (Fig. 2). Levels of significance were estimated using t-statistics derived from a bootstrapping procedure with 1000 re-samples.

Most of our research hypotheses were supported, at least for *non-users*. Overall, the *MedTec-user* model explained major proportions of device (87%) and infrastructure (77%) acceptance, the non-user model explained 55% of device acceptance and 49% of infrastructure acceptance.

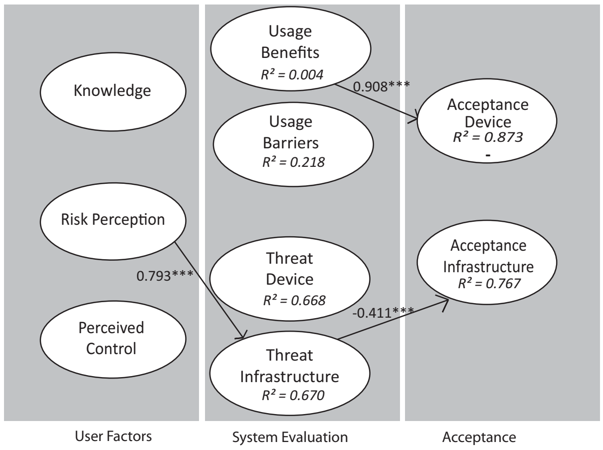

Fig. 1: WMT acceptance model for MedTec-users (*** = p < 0.001).

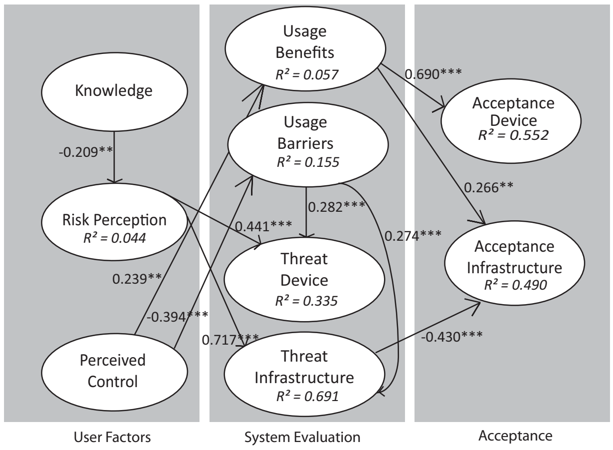

Fig. 2: WMT acceptance model for non-users (** = p < 0.01, *** = p < 0.001).

User factors. Knowledge has a negative effect on risk perception for *non-users*, but no effect on usage benefits or for *MedTec-users* at all (H1a). Risk-perception has a significant positive influence on device threat and infrastructure threat in the *non-user* model and is only positively related to infrastructure threat in the *MedTec-user* model (H1c). Whereas perceived control is only relevant for explaining usage barriers and benefits of *non-users* (H1b).

System Evaluation. Usage benefits are the most important predictor of device acceptance in both groups (H2a). In contrast, usage barriers are only relevant for device threat and for infrastructure threat in the *MedTec-user* model (H2b). However, infrastructure threat is a significant predictor for infrastructure acceptance in both groups (H2d), whereas device threat does not affect device acceptance at all (H2c).

Acceptance. Device acceptance has no impact on infrastructure acceptance in both user groups (H3).

4 Conclusion

The present study investigated the impact of WMT system-architecture (device vs. infrastructure), underlying usage benefits and barriers, and user factors on WMT acceptance by applying structural equation methods. Understanding the determinants of WMT acceptance is not only important for system developers but also for healthcare practitioners responsible for the implementation and employment of WMT. Therefore, apart from a discussion of our findings, guidelines for system designers, training or marketing campaigns will be derived in our conclusion.

WMT acceptance and system-architecture-related differences in WMT acceptance. In general, our findings show, that WMT were positively perceived. Contrary to ICT research findings (e.g. [9]), WMT infrastructure acceptance was higher than WMT device acceptance. We assume that WMT device acceptance was reduced due to the stigmatized image of MedTec device usage. On the other side, WMT infrastructure might be perceived more positively as it gives a general feeling of medical safety. Interestingly, WMT device and infrastructure acceptance were found to be independent from each other, without positive or negative moderating effects. Since the expanding technical infrastructure of WMT in future might influence perceived usefulness (e.g. compatibility to existing devices) but also barriers (e.g. growing sense of control by a increasingly autonomous technology), researchers should not neglect one technology level while analyzing acceptance of the other.

Underlying usage benefits and barriers explaining WMT acceptance. Regarding the sources of WMT acceptance we found, that usage benefits (especially "faster medical help in emergencies") are the strongest drivers of device acceptance, especially for *MedTec users*, whereas infrastructure acceptance is predominantly influenced by infrastructure threat. The specific type of medical technology used in our scenario might explain the rather low importance of "mobility and flexibility" for MedTec-users. For example, patients who have to use a blood pressure or diabetes monitoring on a daily base, might not have noticed a higher flexibility potential due to WMT in the presented scenario. This aspect might be more important for patients who are e.g. confined indoors or bound to healthcare centres at fixed points in time. Interestingly, usage barriers play a minor role in WMT acceptance; they only have an indirect effect on perceived threat in *non-users*. MedTec usage experience leads to a further decrease of perceived barriers. Even though usage barriers act only indirectly in *non-users* on acceptance, they should nevertheless be considered: Enhancing WMT acceptance could be accomplished for example by focusing on problems of "technical reliability" or "data safety" in system design or addressing the aspects of "increased safety due to WMT" or "dependency of technology" in marketing.

Impact of MedTec usage experience and user factors on WMT acceptance. Our findings emphasize the need to differentiate between *MedTec-users* and *non-users*, especially in the context of healthcare. Apparently, MedTec usage experience not only affects the perception of benefits and barriers, but also mitigates the effect of individual user factors such as knowledge, risk perception or perceived control. However, as the (young) *non-users* of today can be regarded as potential future WMT users, the impact of individual user factors on acceptance patterns is highly important for the commercial launch of WMT as well as for compliance-related issues.

Knowledge was found to directly affect risk perception in *non-users*, which considerably influences perceived threats of WMT device and infrastructure. In order to enhance WMT acceptance in *non-users* by trainings or marketing activities it is therefore necessary to a) impart knowledge about wireless technology and b) to specifically address risk perceptions and health fears associated with this technology.

Limitations and future research. Future studies will have to examine larger samples with a higher proportion of actual MedTec-users in order to validate our findings. In order to investigate the causes of the "reversed" WMT acceptance pattern (higher infrastructure than device acceptance), we will contrast wireless technology acceptance in different application contexts (ICT vs. MedTec usage context). Finally, the specific impact and the relationship of device and infrastructure acceptance on actual WMT acceptance and compliance should be studied in more detail.

Acknowledgments. Thanks to Barbara Zaunbrecher for research support.

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